

Roughness plays an important role in streams. It helps determine the depth or stage of flow in a stream reach. As flow velocity slows in a stream reach due to roughness, the depth of flow has to increase to maintain the volume of flow that entered the upstream end of the reach (a concept known as flow continuity). Typical roughness along the boundaries of the stream includes the following:

- Sediment particles of different sizes.
- Bedforms.
- Bank irregularities.
- The type, amount, and distribution of living and dead vegetation.
- Other obstructions.

Roughness generally increases with increasing particle size. The shape and size of instream sediment deposits, or bedforms, also contribute to roughness.

Sand-bottom streams are good examples of how bedform roughness changes with discharge. At very low discharges, the bed of a sand stream may be dominated by ripple bedforms. As flow increases even more, sand dunes may begin to appear on the bed. Each of these bedforms increases the roughness of the stream bottom, which tends to slow velocity.

The depth of flow also increases due to increasing roughness. If discharge continues to increase, a point is reached when the flow velocity mobilizes the sand on the streambed and the entire bed converts again to a planar form. The depth of flow may actually decrease at this point due to the decreased roughness of the bed. If discharge increases further still, antidunes may form. These bedforms create enough friction to again cause the flow depth to increase. The depth of flow for a given discharge in sand-bed streams, there-

fore, depends on the bedforms present when that discharge occurs.

Vegetation can also contribute to roughness. In streams with boundaries consisting of cohesive soils, vegetation is usually the principal component of roughness. The type and distribution of vegetation in a stream corridor depends on hydrologic and geomorphic processes, but by creating roughness, vegetation can alter these processes and cause changes in a stream's form and pattern.

Meandering streams offer some resistance to flow relative to straight streams. Straight and meandering streams also have different distributions of flow velocity that are affected by the alignment of the stream, as shown in **Figure 2.17**. In straight reaches of a stream, the fastest flow occurs just below the surface near the center of the channel where flow resistance is lowest (see **Figure 2.17 (a) Section G**). In meanders, velocities are highest at the outside edge due to angular momentum (see **Figure 2.17 (b) Section 3**). The differences in flow velocity distribution in meandering streams result in both erosion and deposition at the meander bend. Erosion occurs at the outside of bends (cutbanks) from high velocity flows, while the slower velocities at the insides of bends cause deposition on the point bar (which also has been called the *slip-off slope*).

The angular momentum of flow through a meander bend increases the height or *super elevation* at the outside of the bend and sets up a secondary current of flow down the face of the cut bank and across the bottom of the pool toward the inside of the bend. This rotating flow is called *helical flow* and the direction of rotation is illustrated on the diagram on the following page by the arrows at the top and bottom of cross sections 3 and 4 in the figure.